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Electric Railway Traction

Money-Saving Details

IN all branches of engineering a well-thought out detail may be the means of saving a considerable amount of money and trouble, and two such details are described in the present issue of this Supplement. First, the application of carbon wearing strips to pantographs has resulted in a remarkable increase in the life of the strips, and has proved beneficial to the contact wire, although what the ultimate life of the wire will be on a section operated solely by carbon strips cannot yet be determined, as even with copper wearing strips the life is over six years. When carbon strips alone are used over any given section the life of the strips amounts to approximately 75,000 miles, nearly six times as much as the service obtained from copper strips. Secondly, the use of steel contact wires is being tried in sidings and yards in Russia, and for local lines in Italy. If successful, it should appreciably reduce the cost of conversion schemes which include a large proportion of yards. The principal disadvantages against the use of steel are corrosion and high electric resistance, but we suggest that a solution to both problems may be found in the use of copper-bearing steel, that is, steel with but a fractional percentage of copper in its composition.

The Granet Report

THERE are occasional instances in which the benefits brought by electrification are not sufficient to counteract a long and severe trade depression, and such a case is to be found in South Africa where the coal export trade from Durban in particular, and other traffic in Natal in general, have fallen to an ebb which precludes the utilisation of the electrified system at a profit. The Granet Commission enquired closely into the operation of the Natal electric lines (see *Electric Railway Traction Supplement,* February 9, 1934), and in the report which has just been published, which was reviewed at some length in THE RAILWAY GAZETTE of September 21 and October 6, it states the opinion that the effect of this factor in preventing the anticipated savings was intensified by the cost of conversion being in excess of the estimates. Nevertheless, the commission considers that by extending the electrification from Cato Ridge to Mason's Mill, appreciable savings could be effected by the better utilisation of the capacity of Colenso power station. For this reason, and also for the better utilisation of the electric locomotives, it was considered economical to electrify the main line to the Orange Free State between Daimana and Harrismith, a work which the railway administration had in hand when the commission arrived in the Union. Backing has been given to the policy of the management in promoting schemes of electrification which can show economies within the existing sources of power and stock, and in this connection it has just been announced that electrification will be extended from Cato Ridge to Durban, and from Glencoe to Volksrust, on the main line to Johannesburg. On all the present and future extensions discarded rails will be used for contact line masts, in concrete blocks. This is a notable instance of the good which cometh from evil, for it was the relatively high cost of the early conversions which caused attention to be turned to economical methods of overhead construction. The Granet Commission records its opinion that the suburban electrification out of Capetown to Simonstown and Belleville has been justified.

Wheel Arrangements

FROM the very first issue of this Supplement we have consistently urged the adoption of a form of nomenclature for electric locomotive wheel arrangements which would perform its function with clarity and brevity, and be applicable to any layout of axles. With electrification (and diesel-electrification) on the up-grade throughout the world, the matter tends to become of even more importance than hitherto, and therefore it is disappointing to find that in its recently issued publication, *British Standard Engineering Symbols and Abbreviations,* the British Standards Institution has thrown in, merely by way of an *obiter dicta,* a sketchy page and a half purporting to be a guide on the subject. The standards given are not even right so far as they go—and the ground covered would hardly extend from Dan unto Beersheba. For instance, the classification 1C+C1 is given as representing a double-truck articulated locomotive having three coupled driving axles and one pony axle in each truck, the pony axles being arranged outside the six driving axles of the locomotive. If this is right, what is the classification for a locomotive with radial or fixed carrying axles but otherwise similar? Properly speaking, the pony truck is not integral with the main truck frame as is a rigid axle; therefore the wheel arrangement with pony trucks should be 1-C+C-1, and if radial or rigid axles (which are in the main truck frame) are used, then the symbol becomes 1C+C1. There does not appear to be any reason why a pony should be treated differently from a bogie as far as the position of the hyphen is concerned, yet further on the B.S.I. gives 2-B-B-1, although qualifying this by calling the end trucks *non-driving trucks.* Even the 2-B-B-1 formula should have been elaborated to show the difference between a layout with two separate main trucks and a locomotive with a rigid frame having two sets of two driving wheels, each separately driven by one motor, this arrangement being 1-BB-1. No indication is given as to the term to be used for, say, a five-axle locomotive driven by anything from one to four nose-suspended motors, and having all the axles coupled by side rods; nor is there any suggestion as to what should be used for locomotives which are invariably worked in double or triple formation. Finally, no indication is given as to what is meant by articulation; it is possible for a locomotive to be articulated and to transmit both buffing and drag stresses; or the buffing shocks only; or neither the buffing or drag stresses. All the above wheel arrangements or forms of articulation have been built. It is to be regretted that when the subject was being tackled it was not done in a slightly more enthusiastic and workmanlike manner, for within the limits set out in the B.S.I. publication there was little disagreement as regards the terms to be employed.

THE MOSCOW UNDERGROUND

The official opening of the first underground railway in Russia will take place on November 17, the seventeenth anniversary of the Revolution, but a public service will not be started until the end of the year

MOSCOW is probably the only city with over 3,000,000 inhabitants which hitherto has been unable to boast of some kind of railway below surface level, but the tremendous increase in transport requirements, consequent upon the rapid development of the city, has made the provision of an underground system a necessity. The problem has been tackled in the characteristic Russian fashion of planning the complete scheme, and beginning the construction of practically all sections at once. The first section of the new line was to have been opened on the seventeenth anniversary of the October Revolution (November 7 in the English calendar), but this has been postponed until the New Year and only an exhibition opening of a short section on the Sokolniki-Arbat section will be staged on November 7.

It is interesting to recollect that so early as 1900 the question of an underground railway was discussed by the Moscow city council, but the first proposals were squashed immediately by protests from the Archbishop of Moscow and the Russian Imperial Archæological Society that such a railway would gravely endanger the foundations of many churches and buildings of historic interest.

The present proportions of passenger transport in Moscow may be judged from the fact that about 1,700,000,000 journeys were made in the trams and buses during 1933, and with the present rate of development it is anticipated that in 1935 the total will reach 2,500,000,000. The rapid expansion in the transport industry caused the city council (Mossovit) to turn its attention to the provision of more rapid and efficient means of mass transportation, and during June, 1931, the plenum of the Central Committee of the Communist Party, under the leadership of I. W. Stalin and A. M. Kaganovich, resolved to begin investigations on the possibility of a Metropolitan, or Metro as it has become known in Russia, the constructional work on which should be started in 1932.

The General Scheme

The historical development of Moscow on the radial principle, with the main streets radiating from the centre, the Kremlin, made it necessary to build the underground railway also as a radial system, the lines running from the centre to the suburbs along the main streets, each two radial lines being connected as a through diametrical line. The original scheme sanctioned by the Council of People's Commissars on March 21, 1931, sought for the provision of five diametrical lines which, radiating from the centre at Bib. Lenin, Ohotni Riad and Dsershinski Place, would run to the suburbs, every line having a common station with each of the other lines, so that only a single transfer is required to reach any part of the city. This original scheme has been improved by the office of Metroprojet under its chief, Prof. A. Nikolai, in arranging an additional diametrical line and providing a belt line, which, being about 4·2 km. in diameter, crosses all the radial lines, so that should this arrangement be carried out Moscow will have an up-to-date underground railway, with total length of about 110·8 km. serving 89 stations, of which three are at Dsershinski Place and four at Ohotni Riad.

Present Route

The line under construction starts at Sokolniki, from where it runs along the Rusakovskaia Street until the crossing with Gavrikova Street, where the first station is provided. From there the line proceeds along the Krassnorudnaja Street, the next stop being at Kabanchevskaia Place (now Konisornd), where the three main line railway terminals and all the most important suburban terminals are located. Two further stations are provided along the Miassnitzkaia Street, one at Krassnia Vorota (Red Gate) and the other at Miassnitzkaia Vorota; the next station at the Dsershinski Place serves Moscow's most important traffic centre, which will also be traversed by the Gluboki Vood line.

Tunnel near Sokolniki being faced

From here the Metropolitan runs along the Teatvalni Projesd until Ohotni Riad, and from there along Mohovaia Street to Bibliothika Leniana (The State Lenin Library), where the line is divided into two parts, the main one running along Volhousa to the Dvoria Sovitov (Palace of Soviets) and then proceeding along Ostroshenka to the terminus at Krinskaia Place. The second line proceeds under Vosdvishenka to Arbatskaia Place and from there along Arbat Street to its terminal at Smolensiä Rinok (Market). The total length of the line is 7·5 miles of which 5·75 miles are between Sokolniki and Krinskaia

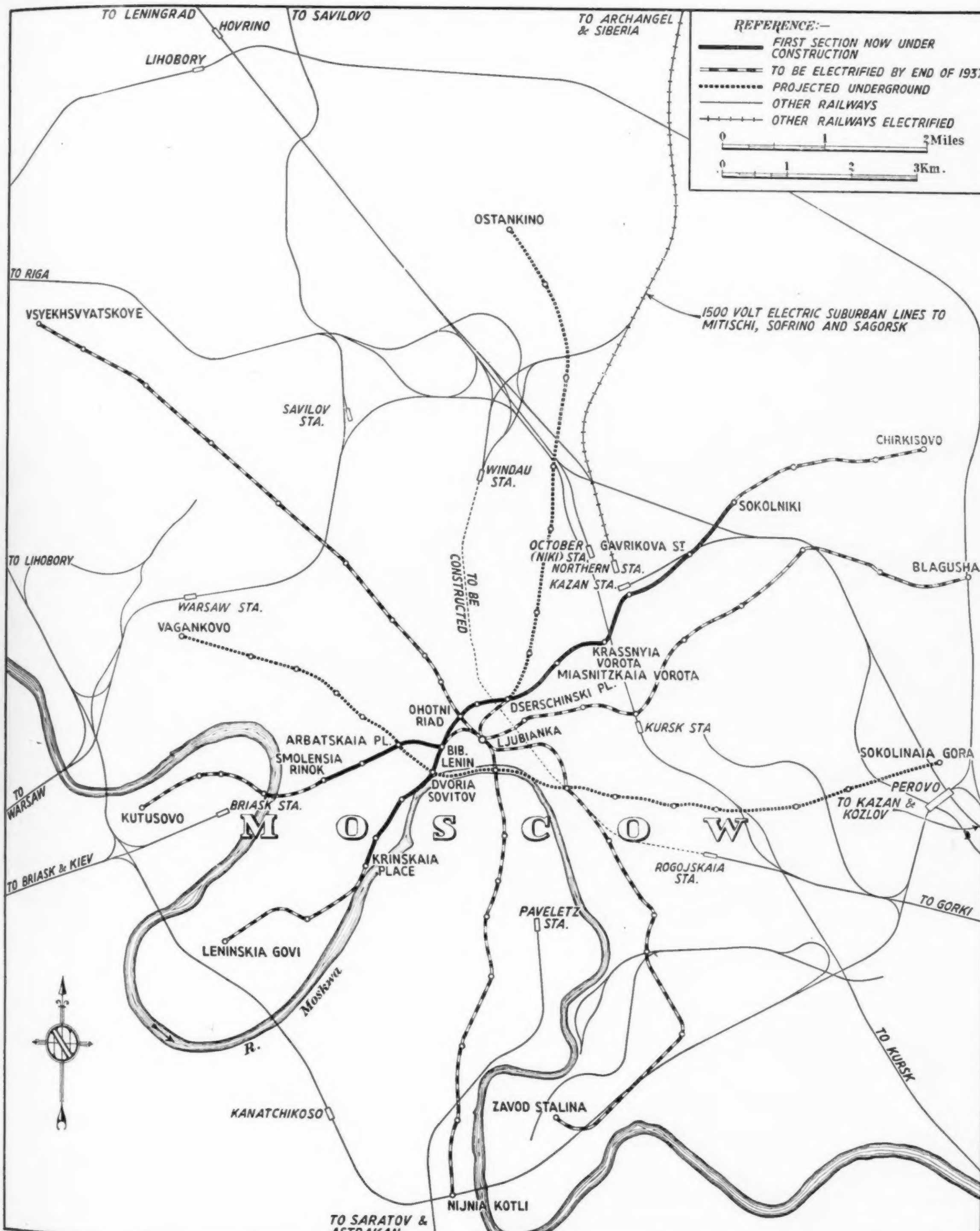


Fig. 1—MAP SHOWING UNDERGROUND, STEAM, AND ELECTRIC RAILWAYS IN MOSCOW

Place, the average distance between stations being 1·8 km. Although the line is built on the cut and cover method at Sokolniki, where traffic is not so intensive as to preclude this, it has been found more advisable, considering

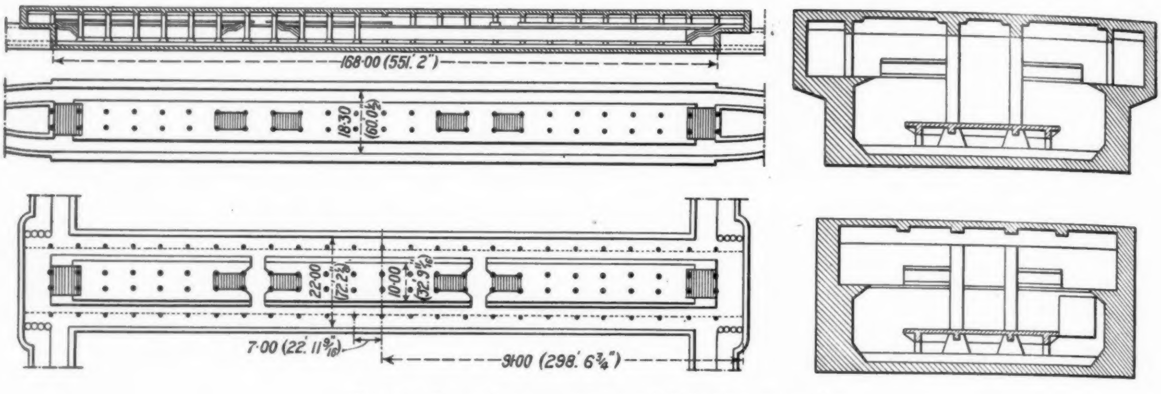


Fig. 2—General arrangement of interchange station

also the geology, to adopt the tube method of construction along the more important streets such as Miasnıtzkaia, Ohotni Riad, Dsershinski, Sverdlov and Komsomolsskaia Places, together with the stations at Bibliothika Lenina, Ohotni Riad, Dsershinski Place, and Miasand Krasnaia Vorota. The Arbat branch from Bibliothika Lenina to Smolensia Rinok will be built on the cut and cover method, but in order to reduce construction difficulties and expenses the line will run not directly under Arbat Street, but under side streets and yards at its left.

At present no station will be made at Dvoria Sovitov, which itself has not yet been built, but the line will be constructed in such a manner as to permit the provision of a station without interrupting traffic. Each station will be built on a different design, and the entrance will be distinguished by a huge capital M. All stations will be built on different designs developed in a competition of leading Russian architects. The main objections sought in developing the station design was to provide friendly and convenient room for the public, entirely eliminating everything suggesting a cellar; so the walls, roof and pillars of most of the stations are to be covered with white and pink marble, some columns being partly covered with black marble for reason of contrast, while artificial lighting is being supplied on some stations through a roof of coloured glass, to create a pleasing effect. Stations are entered directly from the pavement, not from the centre of the road. According to local circumstances and the depth of the railway, stairways, lifts and reversible escalators are installed between the entrance hall and platforms. The standard length of the island platforms is **508** ft. in order to accommodate an eight-car train, and the arrangement of an interchange station is shown in Fig. 2.

Methods of Construction

Local conditions made it difficult to arrive at a decision concerning the method of construction. The city authorities conferred with Russian specialists, and experts from London, Berlin, Paris and New York, and two of the London Underground engineers spent some time in Moscow. The Russian engineers favoured a deep tunnel because it would not disturb road traffic during the constructional period; also, all the men and materials required could be drawn from the Russian mining industry. Despite various other opinions, work on this system was begun in **1932**, but difficulties arose and a programme of mixed construction was adopted, viz. :—

(i) In closely built areas with relatively firm subsoil a deep-level tunnel to be built about **100** to **130** ft. below the surface in strong loam or limestone.

(ii) In broad streets and where the subsoil is not suitable for deep tunnelling, a sub-surface railway to be built by the open method (as in Berlin) with the tunnel floor **30** to **40** ft. below the surface.

(iii) Where the ground water level is low enough and the line can be taken through open spaces and courtyards, the railway

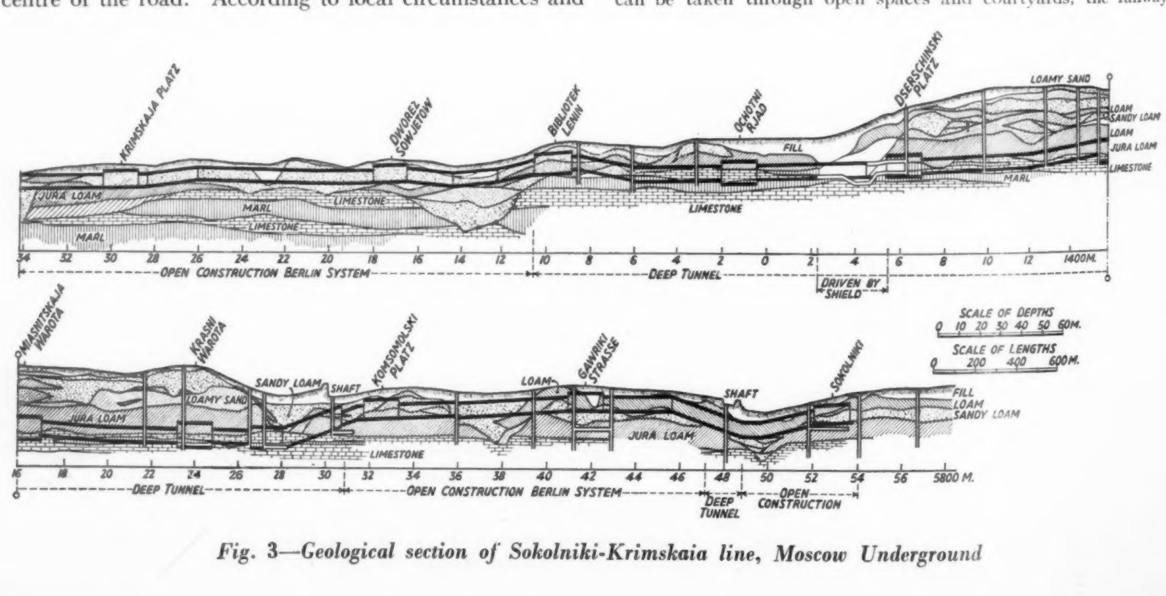


Fig. 3—Geological section of Sokolniki-Krimskaia line, Moscow Underground

is again to be of the shallow tunnel type, but built by the trench system as in Paris.

On this basis, the first 7·5 miles is being built as follows:—

3·125 miles on system (i) above, with 40 shafts and a depth of 15 to 40 metres (49 to 131 ft.).

3·125 miles as shallow tunnel on the Berlin system.

1·25 miles as shallow subway on the Paris trench system.

This involves the excavation of about 2,616,000 cu. yd. of spoil and the use of 1,046,400 cu. yd. of concrete.

The methods used for the later parts of the project will be decided according to the circumstances of each section. In the light of experience gained during the construction of the first sections it seems probable that deep tunnelling will be avoided wherever possible.

Open Construction

The geological profile of the route from Krimskaia Place to Sokolniki shows the elevation of the line, the methods of construction, and the position of the shafts. For a distance of about 1·85 miles the line runs through a street which is so wide that the excavation for the double-track railway could be made alongside the actual roadway without impeding traffic or necessitating the underpinning of buildings, except at the sites of three stations where the width of the excavations, about 82 ft., involved some diversion and underpinning. The ground water level is from 10 ft. to 16 ft. 6 in. below the surface, and the strata traversed include fill, sand, loam, erratic rock, and more or less solid clay.

The walls of the excavations for the open construction on the Berlin system were supported by I-beams rammed to a depth of about 13 ft. below the floor of the subway and braced by timber cross pieces to one or more rows of intermediate I-beams, according to the width of the cut. Retaining planks were fitted between the I-beam flanges down to the level of the ground water, below which sheet piling was employed. No special sections being available for the sheet piling, a substitute was made by riveting together I-beams and channel sections as in Fig. 4. Russian-built electrically-driven reciprocating pumps, spaced 10 to 16 ft. apart along the edge of the excavation and delivering 11-13 gal. per min. against a head of 33-52 ft., dealt quite satisfactorily with water entering the workings. In a number of cases boreholes driven to a depth of some yards in the underlying porous limestone proved very effective as drainage.

Most of the excavating was done by hand. Limited use was made of pneumatic drills. The 75-cm. (2 ft. 3$\frac{9}{16}$ in.) track used in the cut was too heavy for convenience, with the result that most of the material was removed by wheelbarrow or in boxes. Inadequate transport facilities resulted in irregular loading; in fact, all conditions combined to make the removal of spoil one of the greatest difficulties. It is hoped that the use of scraper excavators will facilitate the later stages of construction.

The standard dimensions of the finished subway, as built on this system, are 25 ft. wide by 12 ft. 9 in. high from the running surface of the rails to the underside of the cover beams. Multiple lays of asphalt tarboard are generally used to exclude ground water, but in some places locally-manufactured sheets of asphalt-tow composition are employed.

Deep-Level Tunnel

Forty shafts were sunk to depths of from 50 to 130 ft., the average length of tunnel driven from each being about 109 yards. Great difficulty was experienced in sinking

The first 330 yards of double track

Single track tunnel as built on the French system

the shafts through quicksand, especially as any substantial influx of the latter imperilled adjacent buildings by subsidence. In one instance, where improvised metal sheet piling began to fail, the work was completed by building a compressed air caisson and lining the shaft with concrete. In another case a somewhat similar method was employed, a compressed air lock being built and the sinking of lining rings facilitated by blowing compressed air into the surrounding ground to reduce the friction. The freezing method was also employed successfully, an ice-wall one metre in thickness being formed round a 19 ft. 8 in. shaft sunk close to tall buildings through difficult ground.

After excavating the core of earth inside the frozen shell, a shaft lining of reinforced concrete one foot in thickness was applied. Iron tubing was not employed, owing to the shortage of such material, but the use of concrete necessitated special precautions. The air in the shaft was at about 32 deg. F. and the walls of the excavation were at 10 to 14 deg. F., but concrete sets best at 59 to 68 deg. F. and slowly if at all below 40 deg. F. This difficulty was overcome by heating the concrete electrically, a layer of Chevelin and Ruberoid being first applied to the frozen earth. The cost of the electrical energy consumed amounted only to about 7 per cent. of the total cost of concreting. The results of the freezing process were so satisfactory that it was decided to use the same method in sinking stairway shafts under similar conditions.

The railway enters and leaves the deep-level stations by

single-track tunnels of 18 ft. internal diameter, which merge into double-track tunnels between stations. It was first attempted to build the tunnels by driving a crown gallery, constructing the arch, excavating the lower portion, and completing the walls and floor. This method was satisfactory in dry, firm ground but led to serious flooding and destructive subsidence in other places. Where the tunnel passes through water-bearing strata in the transition between the open construction of the Komsomolski Place and the deep-level section leading to the centre of the city, work is proceeding in compressed air caissons sunk from the surface.

In other places, satisfactory results have been obtained by the chemical solidification of ground by the Joosten process, forming an impermeable canopy above the line of the tunnel or a shell around it as required. The chemical solutions employed are injected through 1-in. tubes driven fanwise 13 to 26 ft. into the ground, which becomes watertight in from 15 to 20 min. and attains a mechanical strength generally ranging from 18 to 55 tons per sq. ft., but occasionally reaching 228 tons per sq. ft. The inspecting tubes are perforated for a length of about 18 in. at their outer ends, and about 3 ft. thickness of ground is thus solidified. The consumption of chemicals is given as about 84 gal. per cu. yd. of ground solidified, and the tunnel has been driven at the rate of 6½ ft.-run per day.

Between the Sverdlov and Dsershinski Places the tunnel passes under the Neglinaja canal and, for a distance of 440 yd., it is being driven by means of a shield obtained from this country. The rate of advance is about 10 to 13 ft. per day, the tunnel being lined with pre-cast concrete blocks weighing 1½ tons each. Russian-built shields are also to be used.

Open Construction

The ground water level between the Bib. Lenin and Smolensia Place is so deep that the railway can here be built as a shallow tunnel without any precautions against infiltration, as is done in Paris. Steel piling as used in the Berlin system of construction is therefore omitted, and the construction proceeds in open cuttings with timber bracing in courtyards and similar situations, short tunnels being driven under the buildings as required. Work proceeds simultaneously on a number of sections, each about 13 to 16½ ft. in length, the walls being first excavated and concreted, after which the roof is built, the enclosed core of earth is removed, and the floor is laid. Intermediate

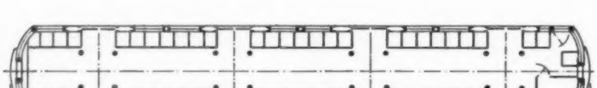


Fig. 4—Seating diagram of car on the Moscow Underground

sections of tunnel are then built, either by open working or by tunnelling according to circumstances. Special importance is attached to the fact that work can be commenced simultaneously along the whole length built by this method, and the operations of excavation and concreting proceed side by side.

Although the general tendency in Russia is to mechanise constructional operations wherever possible, there is a shortage of first-class machines and an even greater shortage of skilled workmen. For these reasons, manual labour predominates in the construction of the Moscow Underground and the total number of workers regularly employed is about 30,000. By covering over the cuttings with planks and insulating material and by the liberal use of steam heating, work has been continued through periods of severe cold, but inadequate haulage arrangements have led to difficulties with frozen spoil, and in many cases the material has had to be re-broken before it could be removed.

Rolling Stock

Power is to be supplied to the trains by direct currrent at 750 volts fed to an under-running rail through a total of four non-automatic substations with an aggregate capacity of 15,000 kW. Trains are to be made up of one motor car and one trailer, each motor car forming a unit with a trailer, the maximum train formation being composed of four such units. Each motor car (see Fig. 5) will have a length of 61 ft., the width being 8 ft. 10 in. and the height 11 ft. 2 in. from rail to top of roof. The car trucks will be in design similar to those of the latest cars of the City of New York. Entrance and exit is by four 4 ft. wide double sliding doors at each side, which are to be opened and closed at stops by air from the driver's position, no handles being provided in order to prevent accidents. Much attention has been paid by S. Kravet, the Metropolitan's chief architect, in creating a pleasing and powerful car appearance. The front end, as well as the roof, is pleasantly curved. Effective ventilation is provided by special ventilators opening on the roof, similar to those adopted in London, by a ventilator opening at the front over the destination sign, and by lowering the side windows to about one-third of their height.

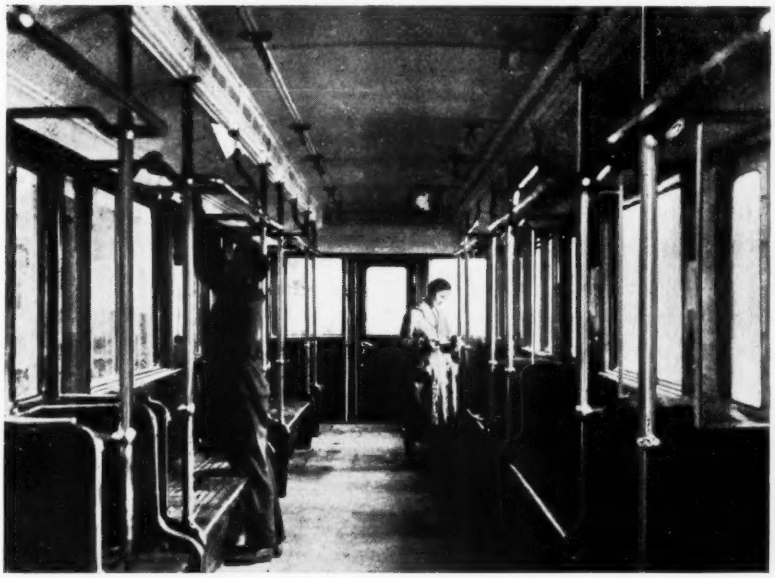
About 55 seated passengers will be accommodated on longitudinal seats, while the total car capacity will be 170, which may be increased to about 250 during rush hours. The seats will be of polished oak, although the adoption of upholstery is under consideration. The side walls will be finished in mahogany, and all metal fittings will be nickel plated. Glass shields are provided to protect passengers seated near the doors from inconvenience caused by passenger movements at stations, while a through hand rail is supported under the roof at each side for the use of standing passengers. Lighting is by two rows of special fittings over the car centre, and by an additional row over the seats at each side. A driver's compartment is situated at one end of each motor car and trailer.

The cars are to be painted blue with a silver waistband under the windows and a grey roof, thus giving a pleasing and harmonious effect. Each motor-car is to be powered by four 205 h.p. motors, the first and third, and second and fourth units being permanently connected in parallel. Both groups are switched in series and parallel by means of fully automatic control with individual electro-pneumatic contactors. Acceleration is governed by a relay, which works within the limits of 80 and 115 per cent. of the average current value, the following step being switched in as soon as the current drops to the former value. The auxiliary circuits are fed from a potentiometer at the low tension of 50 volts. A total of 20 power notches have been provided, ten of which are series and ten parallel; the motor field is shunted on the last power notch. The controller is arranged to enable the speed to be selected by placing the handle in one of the first nine notches, and then by pressing down the dead-man handle to start the train; further acceleration takes place automatically.

The master controller at the driver's left hand has, besides the off and preparatory positions at which the line

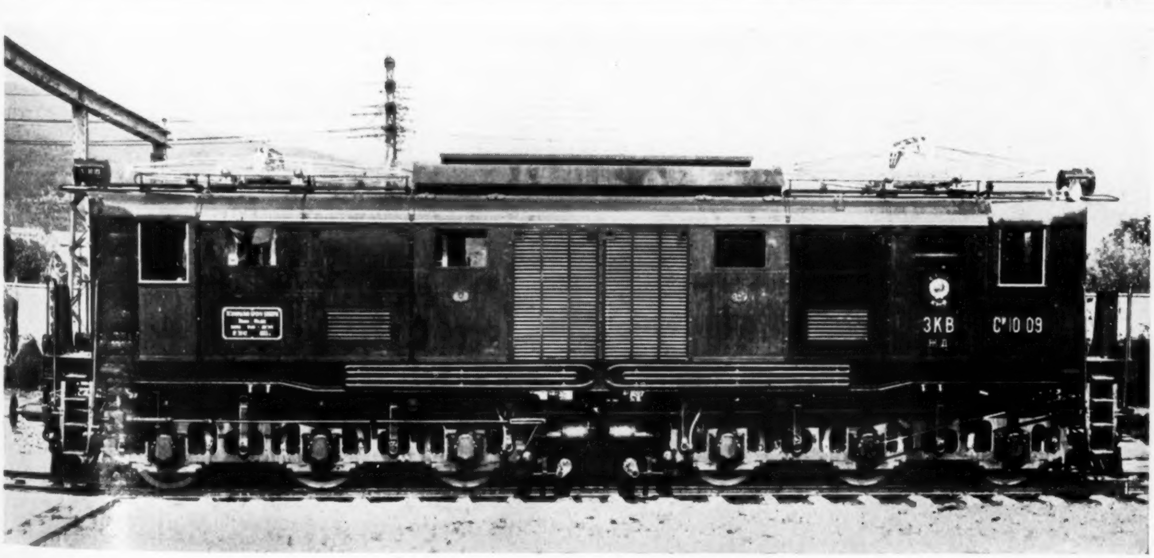
switches are actuated, a total of seven positions, five of which are for forward and two for backward running. At the first forward position both motor groups are switched in series with the resistances; in the second position, required for shunting in yards, the motor groups are connected in series with the resistances cut out. On the third step the groups are in parallel with the resistances switched out, while in the fourth position the motor field is shunted. The fifth position allows of more rapid acceleration up to the final series notch, and in the two reverse positions the motor groups are connected in series with and without resistances respectively.

At the driver's right hand is placed the air brake handle; the sander and whistle are foot-operated. A sliding door is placed at the left side of the driving compartment for the use of the guard, who leaves the car at stations in order to transmit the starting signal to the driver. Willison automatic universal couplers are to be used between the cars, in addition to the usual electrical and brake connections. Each motor car will scale about 50 tonnes, of which each bogie will be responsible for 6 tonnes, the four motors 12·5 tonnes, and the control equipment 4·5 tonnes. The trailers will tare 33 tonnes, and when fully laden the motor cars and trailers will weigh respectively about 70 and 53 tonnes. The maximum speed of the first stock will be only 32 m.p.h., and the schedule speed 16 m.p.h. Automatic colour-light signalling will permit the operation of a maximum of 48 trains per hour. The cars are being built at the Mitischi works, and the electrical equipment at the Dynamo works.



Fitting up the interior of a car on the Moscow Underground

The line now under construction is scheduled to be opened to traffic over the first section on November 7, the 17th anniversary of the Revolution. The whole cost of construction will be about 500,000,000 roubles, of which 370,000,000 roubles were assigned by the Government during 1934. The original project is to be extended to the construction of a line from Sokolniki to Cherkisovo where will be situated the principal car sheds and repair shops. Three new stations will be required, and in the south the line will run two stations further to Leninskia Gori, the Arbat branch being prolonged for some three stations to Kutusovo. The construction of the Underground has been carried out under the immediate direction of P. Rotert and his assistant E. Abakumov, but the great driving force in the whole project has been A. M. Kaganovitch.



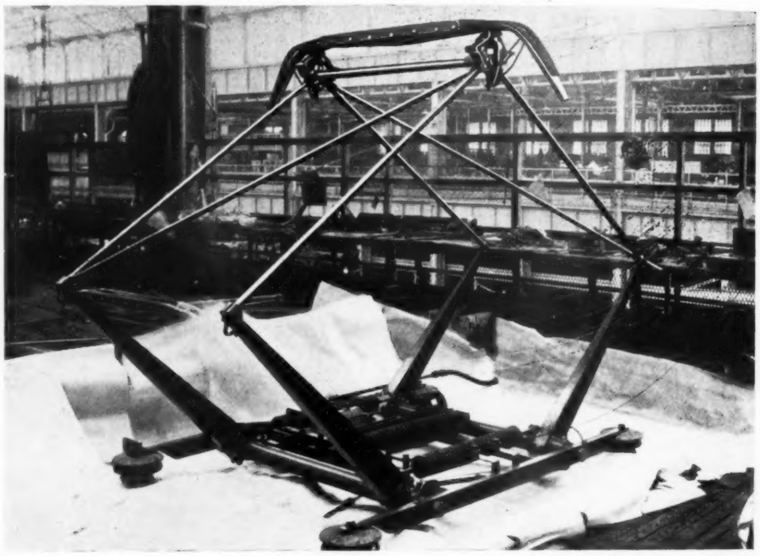
138-ton electric locomotive built for the 5-ft. gauge lines of the U.S.S.R. railways by Tecnomasio Italiana Brown Boveri. The one-hour rating is 3,000 h.p. at 18·3 m.p.h. with a contact line voltage of 3,000

OVERHEAD CURRENT COLLECTION WITH CARBON WEARING STRIPS

Experiences on the direct current lines in Holland

F. WHYMAN, B.Sc.Tech., A.M.I.E.E.

DURING the last few years extensive experiments have been carried out on the Netherlands Railways with carbon wearing strips instead of the usual copper, as it was found that the overhead contact wire was wearing rather rapidly. The resulting experiments had as their main object the reduction of contact wire wear.



Netherlands Railways carbon-strip pantograph in up position

Each of the Dutch motor coaches is equipped with two pantographs, only one of which is in use at a time, and as the result of the experiments referred to above, each motor coach is now being equipped with a single-pan carbon wearing strip pantograph. The other pantograph is to retain the copper wearing strips for the moment, the intention being to use this only in emergency, and in the early mornings in winter, when occasionally the overhead wire is affected by ice.

The Netherlands Railways overhead system has two contact wires, both rubbing against the pantograph collector pan at the same time. The current collection duty of the pantographs consists of a peak current of about 600 amp. with an average current of about 400 amp., the speed of operation being up to 60 m.p.h. Both the single-pan copper wearing strip pantographs and those with carbon strips operate with a contact pressure of 15 lb. per sq. in. It is to be noted that a fairly heavy steam traffic is worked over the same lines.

The following is a brief summary of the results obtained with the different wearing strips:

(*a*) When a line is operated by single-pan copper wearing strip pantograph, the average life of a set of strips is about 13,000 miles. The life of the overhead contact wires varies widely from place to place, but in some cases was as low as six years.

(*b*) When a section of line is exclusively operated by carbon-strip pantographs the average life of the strips is about 75,000 miles. Examination of the contact surface of the wire shows that it reaches a very high degree of polish and that practically no wear takes place.

(*c*) When copper and carbon wearing strip pantographs are operated on the same section of line the overhead wire never attains the high polish produced by carbon strip operation, with the result that the life of the carbon strips varies widely, and the rate of wear of the contact wire is not arrested.

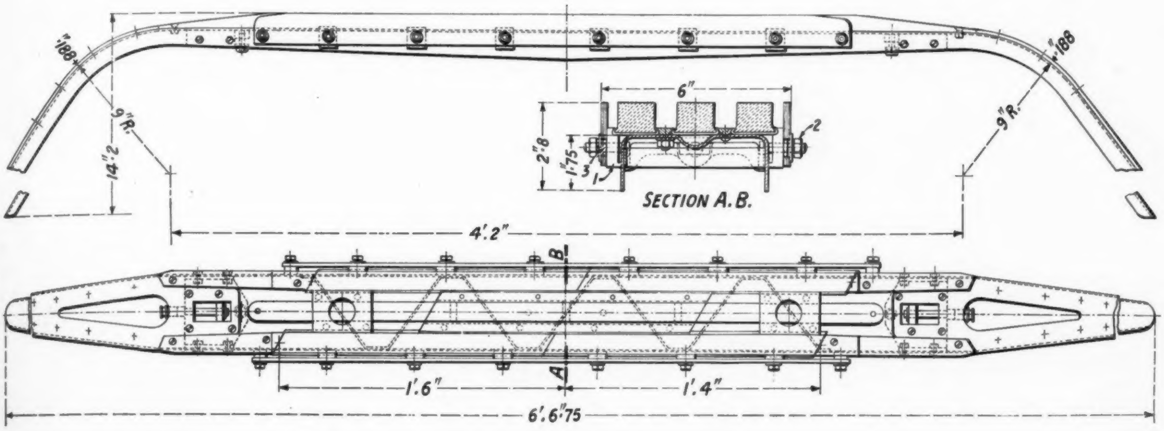
It follows, therefore, that a system must be exclusively operated by carbon strips to obtain the longest life of wearing strips and overhead wire. A further advantage of carbon strip operation is that it is not necessary to use graphite grease lubrication of the collector pans, as it is when copper wearing strips are used. This eliminates slopping of the grease on the car roof and makes the overhead wire more easily handled for maintenance and repair, in addition to saving the material and labour of graphite grease application.

The accompanying illustrations show one of the single-pan carbon collector strip pantographs supplied by Metropolitan-Vickers Electrical Co. Ltd., to the Netherlands Railways. From the drawing reproduced the pantograph may appear unnecessarily complicated, but the complication arises because the steel collector pans used by the Netherlands Railways for copper strip operation have to be modified to accommodate the carbon wearing strips. These pan pressings are only 4·5 in. wide and the arrangement shown allows a total finished width of 6 in. to be obtained. The carbon strips are approximately 17 in. long, 1$\frac{3}{16}$ in. wide and 1 in. thick, five strips being used on each collector pan. The base of the strip is encased in a thin sheet metal carrier, so that when secured in position the clamping forces are taken by the steel carrier instead of the rather brittle carbon. The leading and trailing edges of the collector pan are fitted with strips of $\frac{3}{16}$ in. Bakelite fabric board, which wear down at the same rate as the carbon collector strips and prevent hard spots on the overhead contact wire from chipping the carbon strips.

Fixing of Carbon Strips

At each end of the pan sloping aluminium alloy castings are fitted, butting against the carbon strips to facilitate the passage of the overhead contact wire from the carbon strips to the pan horns, at such places as crossovers. As may be seen from the drawing, the carbon strips are clamped in position by the clamping pieces (1) and the $\frac{5}{16}$ in. bolts. These bolts are welded to the pan pressing. The criss-cross bracing strip is welded to the pan pressing to prevent twisting and possible fracture of the carbon strips.

The Bakelite fabric guards are secured between the clamping pieces (1) and the nuts (2). This ensures that loosening of the nuts (2) will not affect the clamping of the carbon strips, which are clamped by the nuts (3).



Drawing showing the construction of modern carbon-strip pantograph for d.c. current

The carbon strips and Bakelite fabric guards are allowed to wear down about $\frac{3}{4}$ in. before replacement is necessary.

The main requirements of the type of carbon used for wearing strips are:

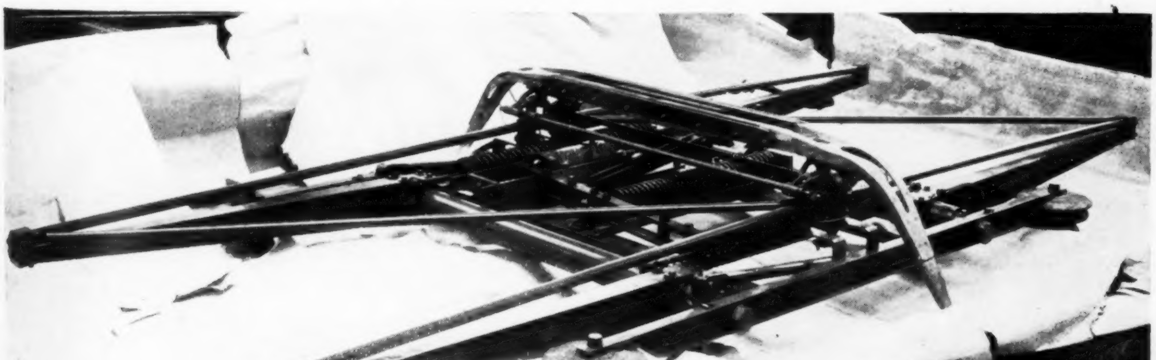
(1) Fairly hard composition.
(2) Low water absorption.
(3) Slightly self lubricating.
(4) Good electrical conductivity.

Low water absorption is very important, as if water is absorbed in any quantity, subsequent freezing causes disintegration of the material. The analysis and test of a sample of material which operates very satisfactorily is given below:

Carbon	95.20	per cent.
Sulphur (mainly as sulphate) ..	1.18	,,
SiO_2	0.80	,,
Fe_2O_3	0.60	,,
Brinell hardness	49.20	,, by volume.
Water absorption	0.61	,, by volume

When there is any considerable volume of steam traffic over an electrified railway, it is always found to result in more rapid wear of the contact wire and the copper strips of the pantographs. This appears quite natural, because grease lubrication of the overhead wire is necessary and the grease film causes the grit and smoke from the steam locomotive to adhere to the contact surface of the overhead wire, producing a kind of abrasive paste which wears the overhead wire and copper wearing strips. Some interesting notes on the adoption of steel overhead contact wires are given on the last page of the present issue of this Supplement; such a system forms yet another possibility for the future, so far as lines with light traffic are concerned.

When a section of overhead wire is exclusively operated with carbon strip pantographs, the steam traffic does not appear to have any detrimental effect on the wear of the overhead wire or the carbon strips. This result appears to be due to the dry conditions of the wire, as no grease lubrication is necessary, preventing the abrasive grit from adhering to the highly polished contact surface.



Metropolitan-Vickers carbon-strip pantograph as used on the 1,500-volts direct current lines of the Netherlands Railways. Pantograph is shown in the locked-down position

Another Swedish Electric Line.—Electric operation has just begun on the Orebro–Krylbo section of the Swedish State Railways, the conversion of which was recorded in the article on Swedish electrification in the issue of this Supplement for December 15, 1933. The short Hallsberg–Orebro line is also worked electrically, giving through communication with the Stockholm–Gothenberg and Tralleborg–Malmo–Hallsberg main lines.

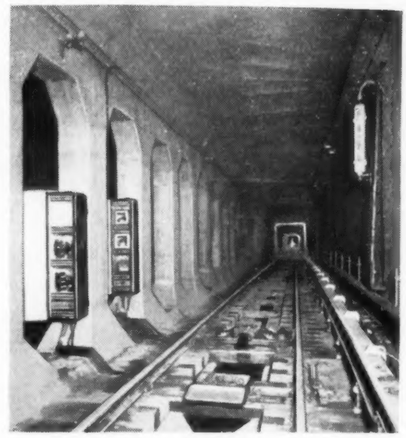
TOKYO ELECTRIC UNDERGROUND RAILWAY

The initial section of the first sub-surface line in Japan was opened in 1927 and has been steadily extended during subsequent years

THE idea of an electric subway in Tokyo was first thought of in 1914, when Mr. T. Hayakawa, the present Managing Director of the Tokyo Underground Railway, was greatly impressed by the working of the London tube lines. The development of the idea was hindered to some extent by the war, but in 1918 a company with a capital of 400,000,000 yen was incorporated, with the object of constructing an underground electric railway from Asakusa in the north, right through the city to Magome in the south.

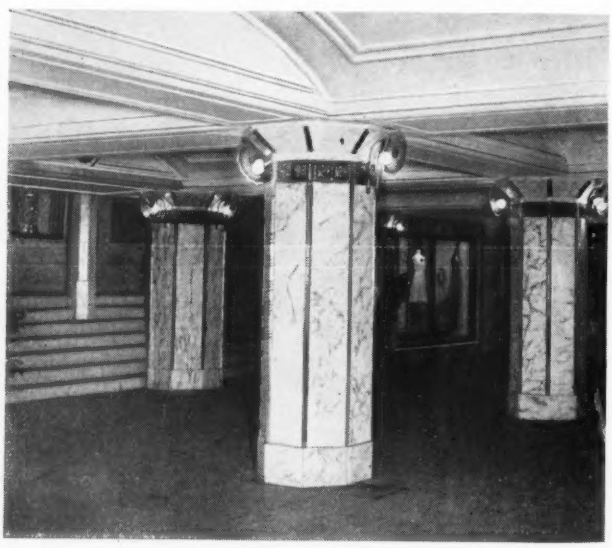
After a great deal of preliminary consideration, work was about to be started when the great earthquake of 1923 occurred and threw back the beginning of construction for two years. As the city was largely rebuilt, some realignment of the underground route was necessary. Tunnelling commenced at the northern extremity in 1925, just 100 years after the opening of the Stockton & Darlington Railway, and proceeded smoothly, so that the first section, from Asakusa to Ueno, was opened to the public on September 27, 1927. Work was pushed ahead and the line was opened to Kyobashi at the end of 1932, and to Ginza, the present terminus, in 1933. The next section, as far as Shinbashi, is to be opened in a short time, and the line will eventually be extended on to Shinagawa.

The whole line from Asakusa to Shinagawa, a distance of approximately 8 miles, is being built by the Tokyo Underground Railway Company, but authorisation has been granted for the construction, under the auspices of the Government and the Tokyo Municipality, of over 40 route miles of underground railway, and it is possible that in a few years' time a transport board will become necessary in order to co-ordinate the operations of the various tramway, bus, and railway undertakings.

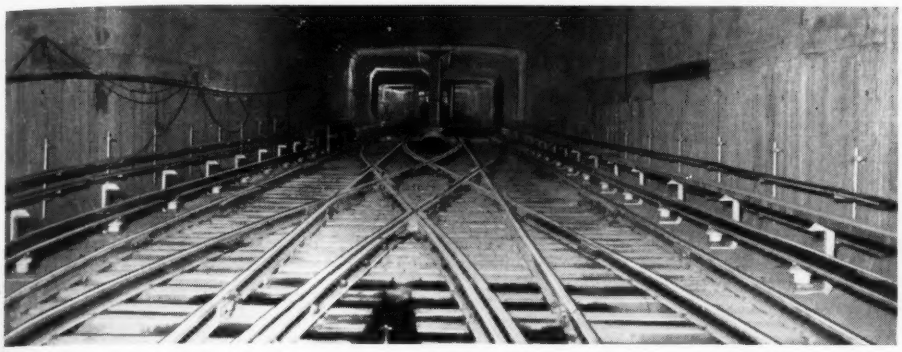


Reinforced concrete tunnel frame, showing signal lights and ramps

For the greater part of the route the Tokyo Underground is but a short distance below street level. The tunnel body is of the double-track box type with a steel or reinforced concrete frame, and the whole structure is as nearly earthquake-proof as possible. Before excavation, steel piles of I-section are driven in both sides of the tunnel; girders of similar shape are laid transversely upon the piles and covered with wood decking to serve as the base for the roadway. Excavation is carried out below the decking and the spoil taken away in skips or elevators. Wooden piles are then fitted between the steel



***Left:* Annexe to side platforms at Uenohirokoji station**
***Right:* Entrance from pavement to Ginza station, the present southern terminus**



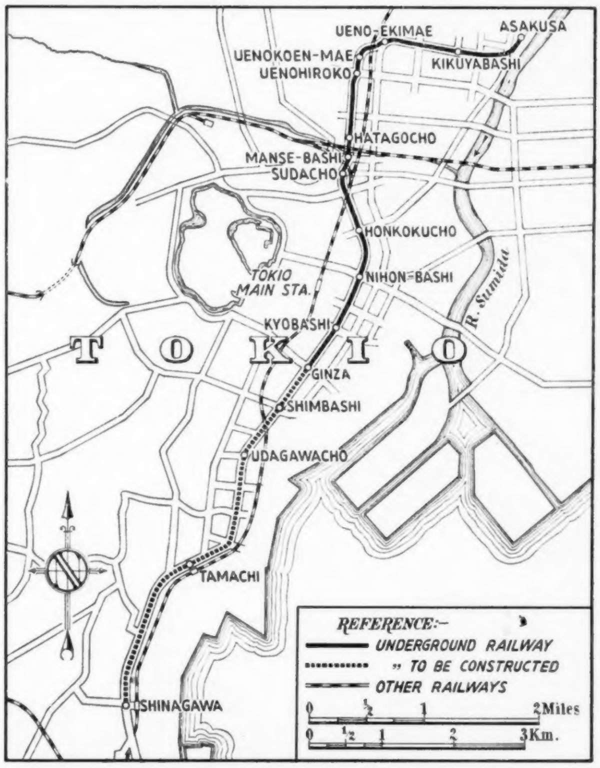
Crossover road outside station on Tokyo Underground Railway

piles and wooden struts inserted to support the sides. After excavation, the tunnel structure is erected, a waterproof layer of asphalt put in, and the surcharge depth of seven feet or more filled with soil. Then the steel piles and beams are withdrawn for further use, and the roadway restored. Tunnels under canals were built by temporarily blocking the water-way with coffer dams, but at some canals a steel trough was laid along the bed to allow of the passage of shipping.

Stations, Stock and Supply

Both island and side platforms are used in the stations, and the length of 300 ft. is sufficient for six-car trains, although the present formation is only two or three vehicles. The cars are of the double-bogie all-steel type, 50 ft. long and 8 ft. 6 in. wide, and are powered by two 120 h.p. motors; they have three mechanically-operated sliding doors on each side. As the platform level is never more than 30 ft. below the street, stairs are used to gain access to the platforms, but in one or two stations escalators have been provided.

The rails weigh 100 lb. a yard and are laid to a gauge of 4 ft. $8\frac{1}{2}$ in.; the minimum radius of the track is 300 ft., and the maximum gradient 1 in 40. Upper contact third rails carry the 600-volt direct current, and are supplied from remotely-controlled rotary-converter substations located at an average distance apart of slightly over a mile. Current for station lighting and signals is also taken from the substations. The headway of the trains is now $2\frac{1}{2}$ min., but the equipment is suitable for operating up to 40 trains an hour. A number of the stations are connected directly with big departmental stores, as well as to the sidewalks of the street.



Map of Tokyo Underground Railway

Electric train at Ginza underground station. This station has stairs leading directly to one of the big departmental stores as well as to the street

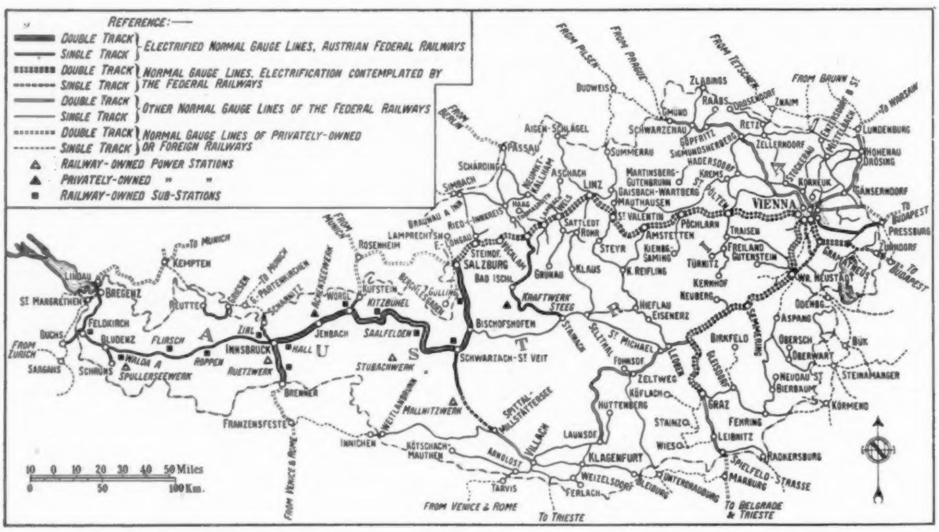
ELECTRIFICATION OF THE AUSTRIAN FEDERAL RAILWAYS

By Ministerialrat E. R. KAAN, Chief of the Department for Electrification, Austrian Federal Railways

THE reasons that have caused railway administrations to introduce electric traction are extremely various, but on the Austrian Federal Railways the following facts were decisive. First, the possibility of procuring energy by exploiting the water power to be found in the country and therefore the independence of at least part of the railway system from other countries from which great amounts of hard coal had to be obtained for the working of the lines; secondly, the mountainous character of the country traversed by the railways; thirdly, considerations concerning the foreign electrified lines which to some extent formed competitive routes. There was also a number of other circumstances of lesser moment.

In pre-war times, the electrification of the Austrian railways was a subject of careful investigation, but no great action was undertaken, mainly because the Austria of that time had extensive high-grade coalfields at her disposal, which the diminished country of to-day lacks almost entirely.

Apart from numerous local lines, and electrified tramways in the towns, electric traction was introduced in pre-war days only on two standard-gauge lines with a traffic similar to that of main lines. These were the Mittenwaldbahn from Innsbruck to Garmisch in the Austrian Tyrol, and the local line Vienna-Pressburg, now Bratislava (see map). After the war the planning was taken up again with new energy, and based on two bills passed in the years 1920 and 1925, which provided the financial foundation, relatively extensive operations towards electrification ensued. These acts provided for the introduction of electric traction on 405 miles of main lines, *i.e.*, on about 11·2 per cent. of the total system of the Austrian Federal Railways (3,628 miles). This electrification programme comprised almost the entire standard-gauge system of the western provinces of Austria (Salzburg, Tyrol, Vorarlberg), and one line in Upper Austria; that is, the lines Salzburg-Innsbruck-Buchs (Swiss frontier) with the branch-lines Feldkirch-Bregenz (German frontier), Innsbruck-Brennero (Italian frontier), Wörgl-Kufstein (German frontier), and Stainach-Irdning to Attnang-Puchheim. This work was done, in the main, by the end of 1929; and from that time until the end of 1932, certain improvements and additions were made. In 1933, conversion work was taken up again, and the electrification of the Tauernbahn (the line Schwarzach-St. Veit to Spittal-Millstättersee) was started. The northern half of this line, as far as Mallnitz, was opened to electric traction in December, 1933, and the second, or southern, portion will be completed by May, 1935. A length of 435 miles of main-line, that is to say 12 per cent. of the whole system, will then have been electrified in post-war years. The extent of the electrified standard-gauge lines operated by the Federal Railways, including the electrification carried out in pre-war times, will then amount to 514 miles, or 14 per cent. of the system. This work of electrification represents the greatest centralised technical achievement of Austria since the war. Further proof of this statement is to be found in the sums expended upon electrification, which, including the line still under conversion, will amount to about 337,000,000 Austrian schillings, or about £12,500,000.



Map of Austrian Federal Railways show lines electrified and to be electrified, and the location of the hydro-electric power stations and the sub-stations

This action has done much towards the reduction of unemployment during the last 15 years. On the average, 10,000 workers a year were employed; in the building season at times up to 30,000. The character of electrification ensures that orders for supplies are distributed among nearly all branches of industry and trade, and it was especially this work-producing effect—besides the economy and other advantages that electric traction brings in its train that caused the work to be taken up again in 1933-34, when the Austrian Government placed the amount needed at the disposal of the Federal Railways. These amounts came from the funds of an internal loan raised for the purpose of procuring work for the unemployed.

For all the lines mentioned, including those electrified before the war, 16⅔-cycle single-phase alternating current

with overhead equipment was adopted, after exhaustive studies, which indicated that this system was the most suitable for Austrian conditions. A factor influencing the decision was that the neighbouring states, Germany and Switzerland, had already adopted this system. This is not the case with Italy, where three-phase alternating current is used in the northern provinces, but the difficulties at the single frontier station so far equipped for electric traction, Brennero, have been solved.

The supply of energy for the electrified system is obtained mainly from four hydro-electric power stations, the property of the Federal Railways, which have been built in the provinces of Vorarlberg, Tyrol, Salzburg and Carinthia. Additional electric energy is supplied by two hydro-electric power stations in private hands, viz. the Achenseewerk in Tyrol, and the power-station at Steeg in Upper Austria. The four power stations belonging to the railways are the Spullerseewerk, the Ruetzwerk, the Stubachwerk and the Mallnitzwerk, all of which are shown on the accompanying map. These four power stations together are capable of supplying about 150,000,000 kWh. a year. The installed plant capacity at present amounts to about 67,000 kW., but the capacity could be increased without necessitating alterations to the buildings.

In consequence of the reduction of traffic caused by the general depression, only two-thirds of the capacity of the railway-owned power stations is made use of at present. These stations have supplied the following amounts of energy since 1930:

	Millions kWh		Millions kWh
In 1930	101·6	1932	101·2
1931	95·9	1933	102·9

Noteworthy among these power stations are the Spullerseewerk, with an available fall of 800 m. and a natural lake turned into a reservoir with a capacity of about 13,000,000 cu. m. of water and the Stubachwerk with an available fall of 521 m. and a natural lake built out into a reservoir with a capacity of 21,000,000 cu. m. of water.

The energy produced in these power-stations is conducted by means of transmission lines with a voltage of 55,000, to 13 sub-stations where the high tension current is transformed to 15,000 volts for the overhead equipment. Some of the substations have the high tension apparatus placed out of doors. The overhead equipment has been carried out in recent years according to a standard system in which the catenary and contact cables are carried by iron poles, the strain of both of which can be retained automatically. The contact line is noteworthy for the fact that the outriggers that carry the system move sideways. The insulation is single except in the case of tunnels. In large stations and yards the overhead equipment is suspended on the cross-catenary system.

The Spullersee hydro-electric power station of the Austrian Federal Railways

The reservoir and dam of the Stubach hydro-electric power station in the Tyrol

In order to collect experience, electric locomotives of totally different types and one class of motor coach were obtained. For express trains on mountain lines, where there are gradients up to 1 in 30, the type of locomotive in use is 1-C-C-1, the weight of which is 115·6 tons and the output per hour is 2,280 h.p. A later class of express locomotive has the 1-Do-1 wheel arrangement, a weight of 112 tons, a maximum speed of 62 m.p.h. and an output on the hourly rating of 3,050 h.p. The experience gained with the various types of engine has made it possible to concentrate for the future on a few standard types.

Apart from one type for shunting locomotives, it is expected that two standard classes will suffice, viz., one express locomotive with a speed of 62-68 m.p.h. (any

greater speed being impossible in Austria, at present, in consequence of the conditions and construction of the lines) probably the 1-Do-1 type and one class for passenger and goods trains, with a maximum speed of 90 km. p.h. (56 m.p.h.) of the Bo-Bo type, six locomotives of which have been ordered already. Further, two specimens of a light locomotive have been ordered that are remarkable for the fact that the complete electric equipment is placed in the frame and bogies, so that the space inside may be used as a luggage van and for mail purposes. Lastly, a trial-specimen of a light electric motor coach has been ordered.

Year	Millions of train-miles			Thousand-millions of gross ton-miles		
	Entire system	Electrified lines	Per cent.	Entire system	Electrified lines	Per cent.
1930 ..	34·34	5·51	16·0	9·66	1·59	16·5
1931 ..	32·80	5·55	16·9	8·86	1·55	17·5
1932 ..	29·35	5·42	18·5	7·37	1·36	18·5
1933 ..	29·30	5·51	18·8	7·20	1·37	19·0

The development of electric traction can be clearly seen from the above table, which shows the traffic results of the entire system, and those of the standard-gauge lines electrified, and comprises the years after the completion of the great scheme of electrification. These are about 462 miles of lines or 12·9 per cent. of the entire system of the Austrian Federal Railways.

Year	Entire cost of energy, millions of Austrian schillings*	Energy used ex power station, millions of kWh	Cost of energy per kWh Groschen*	Cost of energy in the railway-owned power-stations, ex power station. Groschen*
1930 ..	10·95	135·6	7·90	6·0
1931 ..	11·20	129·6	8·42	6·4
1932 ..	11·26	125·0	8·81	6·3
1933 ..	11·20	123·9	8·85	5·9

* One pound sterling is equal to about 26 Austrian schillings at present. The Austrian schilling is divided into 100 groschen.

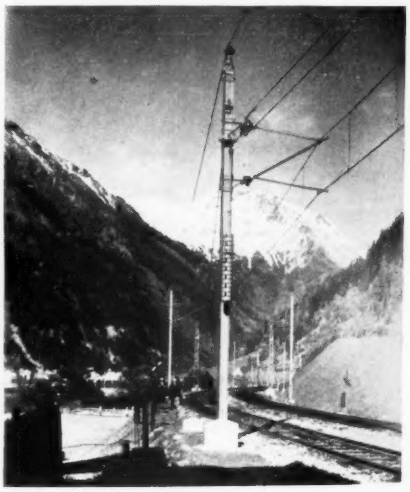
The annual costs of energy are shown by the above table. They include the costs for the running of the power stations, and interest and depreciation charges on the invested capital for the power stations, transmission lines and substations.

The personnel and material expenses alone for running and upkeep of the single parts of the system of the electrified main lines to the west of Salzburg, for instance, in 1932 amounted to:

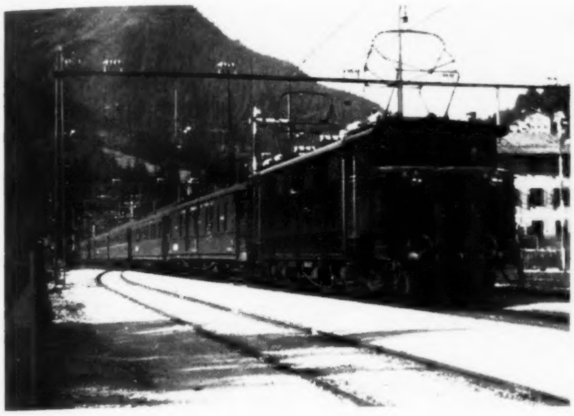
Four railway-owned power stations	Transmission lines, about 310 miles	12 Substations	Overhead equipment, about 680 miles
Austrian schillings			
500,000	400,000	480,000	810,000

As far as the available funds permit, the Federal Railways intend to continue the electrification on a number of other lines, including the Vienna-Salzburg, Vienna-Graz, Vienna-Hegyeshalom lines, and a number of connecting lines between the Graz and Hegyeshalom routes, as shown on the accompanying map. Together, these lines comprise an extent of 414 miles, and their conversion would raise the proportion of the electrified lines of the Austrian Federal Railways to 27 per cent.

Although the present reduced traffic and unfavourable conditions of the money market retard the undertaking of these great tasks of electrification, it is to be hoped that the recovery of the general economic conditions, symptoms of which are appearing also in Austria, may enable these measures to be carried out. It is especially desirable that the line Vienna-Salzburg, which to-day is the most important line of the Federal Railways, should be electrified. It is connected at Salzburg with the western system of Federal Railways, which is already electrified, and with the electrically-worked Bavarian lines of the German State Railway. Such a conversion would bring about electrically hauled through traffic, on the one hand, from Basle and Geneva, on the other, from Stuttgart via Munich and from Salzburg to Vienna. If the Vienna-Hegyeshalom line was also electrified, the result within a measureable space of time would be a direct electric connection from Geneva to Budapest, a distance of 883 miles, as the Hungarian State Railways will have completed the electrification of the line Budapest-Hegyeshalom by the end of this year.

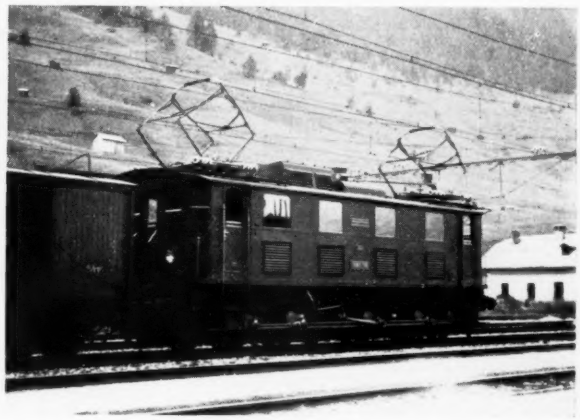
Methods of overhead construction on the 15 kV. single-phase lines of the Austrian Federal Railways



East-bound Arlberg-Orient express at St. Anton, hauled by 1-Do-1-type locomotive

West-bound Bucharest-Paris train hauled by a 1-C-C-1 locomotive piloting a 1-Do-1 machine

Local train in the Arlberg hauled by 1-C-1-type electric locomotive with rod drive



Electric locomotive of the E. 1080 class; this type has three nose-suspended motors, but all the axles are coupled by rods

Electric locomotive of the E. 1082 class with converter for changing the single-phase line current to d.c. for feeding the motors

Overhead line repair wagon. This vehicle is equipped with electric drive, but has also a petrol engine for use when the contact line is dead

VIEWS ON THE ELECTRIFIED LINES OF THE AUSTRIAN FEDERAL RAILWAYS

Photographs by Duncan B. Mackenzie, Esq.

TRIALS OF STEEL CONTACT WIRE

The relative scarcity of copper in the U.S.S.R. has resulted in experiments with steel contact wires for sidings and yard lines where traffic is very limited

IN any comprehensive electrification scheme there is quite an appreciable mileage of sidings and secondary track which is not used by the power vehicles to any great extent, and never for any large current demand. Nevertheless, under the systems hitherto prevailing, copper overhead wires have been used and have accounted for a capital expenditure on which it was hardly possible to obtain an adequate return of use.

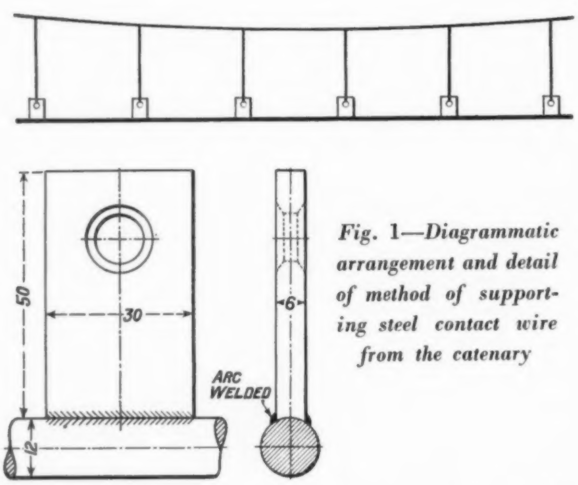


Fig. 1—Diagrammatic arrangement and detail of method of supporting steel contact wire from the catenary

The ramifications of the second Five Year Plan having made a considerable drain on the copper resources of the U.S.S.R., the Soviet Scientific Institute of Railway Electrification took up the question of using steel cables for overhead contact wires and catenaries, and, based on the recommendations of this body, trials have been made with round steel wire on the Leningrad-Peterhof division of the October Railway, the suburban line running from Leningrad along the south shore of the Gulf of Finland to Oranienbaum.

Low electric conductivity and liability to corrosion are the main disadvantages of steel for overhead lines, and at present its use is limited to tracks with light traffic. The comparative properties of steel and copper as used on the October Railway are as follow:—

	Copper wire	Steel wire
Specific gravity	8·96	7·85
Co-efficient of linear expansion ..	0·0000168	0·0000118
Tensile strength, tons per sq. in. ..	22–23	32–38
Specific electric resistance	0·0175	0·126 to 0·14

Round steel wire with a diameter of 12·2 mm. (0·481 in.) and a cross section of 117 sq. mm. (0·181 sq. in.) has been used, in lengths of 40 to 80 m. (130 to 160 ft.), the separate lengths being welded together. The length of wire welded into a single unit was then subjected to a tension of 1,200 kg. (2,650 lb.) and straightened with a hammer and a piece of oak.

Steel plates, 30 mm. by 6 mm. (1·18 in. by 0·235 in.), were then welded to the contact wire by means of a portable arc welding set as used for bond welding, and the plates secured to stringers dropped from the catenary, the details and arrangement being as shown in Fig. 1. As the wire warped somewhat during the welding process it was necessary to straighten it again. Owing to the short length of the anchor sections, 250-350 m. (820-1,150 ft.), no tensioning weights are used. At fixing points the contact wire is carried by welding to it a plate with bevelled top edges, which is secured by a clip holder, as indicated in Fig. 2. After the contact and catenary lines were fixed in position they were cleaned by steel brushes and greased in order to prevent corrosion.

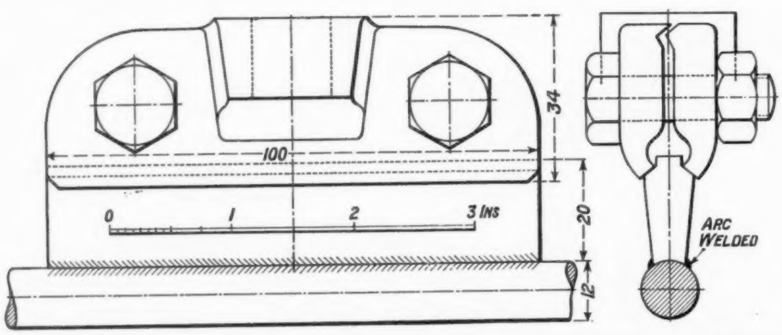


Fig. 2—Detail of the fixing piece used at the end of each length of steel contact wire, October Railway

German Electrification Activities.—An extension of the Bavarian-Wurttemberg electrified system of the German State Railway has just been completed by the opening to electric traction of the 30-mile Tubingen-Plochingen branch, which leaves the main line about 25 miles south of Stuttgart. Conversion work on the 86-mile trunk line from Augsburg to Nurnberg is being pushed ahead rapidly. It is expected that fast multiple-unit articulated trains will be used for the passenger traffic on this division.

Italian-Built Locomotives for the U.S.S.R.—Several double-bogie electric locomotives have recently been built in Italy for the mineral lines round Magnitogorsk, in the Urals. These units are for operation on a 3,000-volt d.c. system, but are of an entirely different design from the seven locomotives sent to Russia from Italy last year (see illustration on another page of this Supplement), and the standard Co-Co locomotives built in the Russian factories. They have four nose-suspended motors with twin gears, and the cab is of the centre, or steeple, type.

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